Wave Induced Bubble Clouds and their Effect on Radiance in the Upper Ocean

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LONG-TERM GOALS

A goal of this project is to measure wave induced bubble clouds and their effect on radiance in the upper ocean and to address the fact that despite the fundamental importance of optical backscatter in the ocean it is still not possible to explain more than 5 to 10 percent of the particulate backscattering in the ocean based on known constituents even during periods with no active wave breaking (Terrill & Lewis, 2004). We intend to investigate the role of upper ocean bubbles in these processes. In this work we are working closely with David Farmer at GSO/URI.

The role of manmade and natural surfactants in upper ocean processes is presently also poorly understood. Therefore, a second goal of this project is to improve on our understanding of how these surfactants modify the bubble field, the surface wave field and ultimately the upper ocean radiance.

OBJECTIVES

During this project, which is a component of the much larger RadyO project, we are addressing the following scientific questions:

- How does radiant light fluctuate beneath a sea in which waves are breaking?

- Can this variability be explained in terms of measured bubble populations with wave scattering models using Mei theory as a kernel for light-bubble interactions?

- Can a predictive model be developed for radiant light that includes wave conditions and predicted subsurface bubble injections?

The presence of surfactants on the surface of the bubbles decreases their buoyancy and therefore their rise speed. The presence of compounds on the bubbles will also modify their dissolution rate and will therefore change the dynamics of the temporal and spatial evolution of bubble clouds and their size distributions. Bubbles are effective at scattering light; thus a proper understanding of the role of surfactants on the bubble field is important to understanding observed radiance modulations.

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With our collaborators at URI and the larger RadyO group of investigators, we will measure and model bubble injection and radiance fluctuations in the upper ocean during wave-breaking conditions. The critical measurements of bubble size distributions and the way in which they evolve with time after wave breaking, will be carried out using an array of acoustical resonators and dense bubble clouds will be monitored with conductivity cells. The surface wave field will be measured with an array of Doppler sonars. The radiance distribution will be measured on meter length scales in the top 10 m of the ocean by other RadyO participants. The bubble clouds will be further characterized with optical systems and sonars.

To improve on our understanding of the role of the microlayer and the microlayer surfactants we are also addressing the following scientific questions:

- What is the spatial and temporal variability of the air-sea interface microlayer and how does the surfactant concentration and composition vary throughout the onset and decay of wind events?

- How does this variability relate to observed variability in the horizontal and vertical bubble size distribution?

- What are the effects of these surfactants on the scattering properties of bubbles?

- What are the effects of microlayer surfactants on radiance fluctuations in the upper ocean?

APPROACH

The instruments and technology for carrying out this work have been developed collaboratively by the PI and his collaborator David Farmer and as part of a program to study the role of the microlayer in air-sea gas exchange processes. This instrumentation is presently being modified to suit the specific requirements of the upcoming RadyO field campaigns. The instrumentation required to detect tiny bubbles (radius < 10 μm) is presently being developed as part of a separate, but obviously connected, project (N000140610379).

The core of the work this year consists of preparing for the field campaigns from Scripps Pier in January 2008, and from R/P FLIP in September 2008 and in 2009. During the Scripps Pier experiment bubble size distribution measurements will be made in the surf zone along the pier to allow for comparisons between our acoustical approach and independent optical measurements using the Wet Labs MASCOT and the Satlantic Inc. IOP profiler.
During the deep water FLIP based measurements the following measurements will be made (Figure 1):

- The primary source of bubbles is from breaking waves; we need to know when waves break, their speed, size and other properties required to describe them. We will determine this by video recordings from a camera pointing at the required slant angle and azimuth so as to comfortably include the area of interest.

- The size distribution of bubbles will be measured continuously at different depths with a set of acoustical resonators operating over the frequency range 20kHz to 1MHz.

- Dense bubble plumes will be characterized at a few points in depth using air fraction sensors detecting electrical conductivity.

- The broader distribution of the bubble cloud will be measured with a sonar mounted on a surface following frame supporting the other sensors.

- Gas dissolution which shapes the bubble size distribution will be measured with a gas tension device and a dissolved oxygen sensor so as to get both dissolved oxygen and nitrogen, which is required for accurate bubble dissolution calculations.

- The sound speed profile and vertical temperature field will be measured with an array of thermistors.

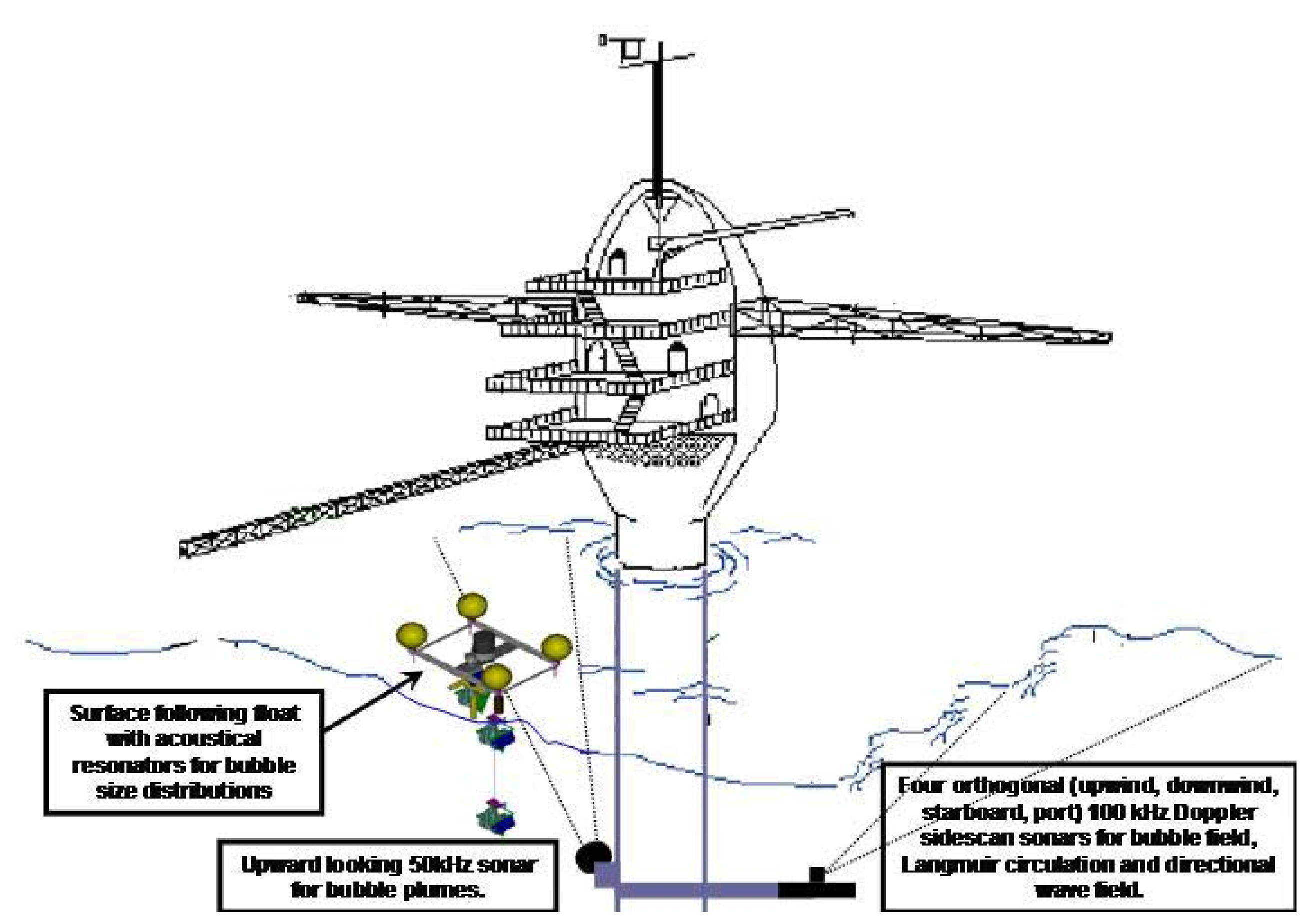

Figure 1: Diagram showing the planned IOS components to be mounted on and deployed from FLIP during the upcoming field experiments. A surface following float with acoustical resonators will measure the bubble size distribution at several depths. An upward pointing sonar, mounted on FLIP or below the float will measure the vertical extent of the bubble field and 4-orthogonal 100kHz Doppler sidescan sonars mounted on the hull will give the directional wave field and the spatial bubble field. In addition we plan to mount a video camera on FLIP to determine when waves break over the float and several other sensors on the hull to measure gas concentrations and the relative water motion.

To address the role of the microlayer and microlayer surfactants the surface water will be collected using a radio controlled rotating disk sampler. Samples will be analysed using an Ocean Optics fluorescence spectrometer operating in the 300-950nm band. Samples will also be collected for further analysis back in the laboratory.

WORK COMPLETED

The microlayer sampler to be used in the RadyO experiments is currently under construction and is scheduled for ocean testing in late October 2007. The graduate student (Masaya Shinki) supported to do the microlayer work has completed his university courses and is working full time on preparing the sampler.

An acoustical resonator with a frequency bandwidth of 4kHz to 1MHz (Bubble radii between 3.5 and 500 μm) has been assembled and will be tested at MVCO in October 2007 and again at Scripps Pier in January 2008.

The 4-channel 100kHz Doppler sidescan sonar that will be used for wave and bubble measurements during the upcoming FLIP experiments has been assembled and is presently being tested on a tripod deployed in Johnstone Strait, British Columbia.

RELATED PROJECTS

The development of a high-frequency, tiny bubble detection device is progressing under a separate RadyO project (N000140610379). This project is also highly integrated into several of the other RadyO projects under preparation.

REFERENCES

Terrill, E. & M. Lewis, 2004, Tiny bubbles: and overlooked optical constituent. Oceanography, 11, 11.